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# Effect of Fallowed and Cultivated Land Use Systems on the Composition and Abundance of Soil Macroinvertebrates Assemblage in Uruk Osung Community, Akwa Ibom State, Nigeria

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## ABSTRACT

*This study was to assess the effect of fallowed and cultivated land-use systems on the abundance of soil macroinvertebrates assemblage. Collections of soil samples were carried out fortnightly twice a month for four months. The extraction of soil macroinvertebrates was carried out using Berlese-Tullgren funnel extractor, and elutriation technique. The mean values of 6.93+/-0.25 were recorded for pH, 32.08+/-0.52$^o$C for temperature, 15.60+/-1.22 for moisture content, were recorded for fallowed soil, and 4.43+/-0.16 (pH), 30.95+/-0.19$^o$C (temperature) were recorded for cultivated soil. A total of 17 soil macroinvertebrates species comprising of 11 orders, from four classes were encountered. Out of the 517 individual soil macroinvertebrates encountered, 327 individuals representing four classes were present in the fallow land while 190 individuals representing three classes were present in the cultivated land. The most dominant species in terms of abundance in the fallowed land site included; Cryptotermes sp 67(20.49%) > Blatta sp 56(17.12%) with Hogna sp 1(0.0.30%) the least; while Cryptotermes sp. 79(41.58%) >Lasius sp 30(15.79%) > Lumbricus terrestris 21(11.05%) represents the dominant species in the cultivated soil with Paraponera sp 1(0.53%) the least. Soil temperature showed positive correlation with the abundance of Clitellata ($r = 0.851$; $p < 0.05$) and Insecta ($r = 0.826$; $p < 0.05$) and Soil pH showed positive correlation with the abundance of Diplopoda ($r = 0.911$; $p \leq 0.05$). In conclusion, it could be deduced from the study that human activities in the cultivated site perturb soil macroinvertebrates community structure which is reflected in the relative abundance of soil macroinvertebrate from the two sampling sites. The results obtained in this study could be a piece of pointing information for the conservation and management of the soil macroinvertebrates giving their functions in balancing agroecosystems.*

**Keywords:** Macro-invertebrates, Fallow land, Cultivated land, Berlese-Tullgren funnel extractor

## 1.0. Introduction

The soil represents one of the most important reservoirs of biodiversity. It is a dynamic, complex, and highly heterogeneous ecosystem that allows the development of a large fragmented number of ecological habitats. It is home to all arrays of living organisms that perform important functions for the soil ecosystem according to their niche (Menta, 2012). The health of the soil ecosystem is therefore relative to its productivity and sustainability which depends on the changing state of its physico-chemical and biological properties (Somasundaram *et al.*, 2013; Elias *et al.*, 2019; Bufebo and Elias, 2020).

According to Nanganoa *et al*. (2019), the physico-chemical and biological properties of soil ecosystems are continuously influenced by land uses. The nature of the soil structure, whether

fallowed or cultivated can exert a strong influence on the diversity and abundance of soil macroinvertebrates in a (Barrios *et al*., 2002; Barrios *et al*., 2005; Moreira *et al.,* 2008). A fallowed land system with its retaining features such as fallen logs and leaves litters provides habitats to many soil and litter-dependent arthropods. In addition, fallowed land with its stable and isolated features with little or no human disturbance over a given time often shows a high diversity and abundance of soil macro-invertebrates species composition (Lagerlöf *et al*., 2002; Rossi *et al.,* 2010). Whereas, cultivated land, with the absence of soil surface litter and tree shadings, exposes these soil macroinvertebrates to an unfavourable conditions such as changes in soil temperature and pH, loss of moisture, and predation. This degraded soil condition could lead to a reduction in the soil macroinvertebrate diversity and abundance (Rossi *et al.,* 2010).

Macroinvertebrates fauna found in soil and soil litter is known to play a crucial role in soil processes such as nutrient cycling, organic matter decomposition, and improvement of soil physical attributes such as aggregation, porosity, and water infiltration (Dangerfield and Milner, 1996; Rossi and Blanchart, 2005; Mutema *et al.,* 2013). There is scanty information on the effect of fallowed and cultivated land-use systems on the composition and abundance of soil macroinvertebrates assemblage in this part of Akwa Ibom state, herein this study to investigate the effect of fallowed and cultivated land-use systems on the composition and abundance of soil macroinvertebrate assemblage in the community.

## 2.0. Materials and Methods

### *2.1. Study area*

The study was carried out at Uruk Osung Village in Obot Akara Local Government Area of Akwa Ibom State, South-South part of the country, Nigeria. Obot Akara Local Government Area lies between $5^0 16' 0''$ N and $7^0 36' 0''$ E. Uruk Osung is within the tropical rainforest belt characterized by a rainy and dry season - the rainy season lasting from late March to early November and the dry season from late November to early March. The forest in the area is of secondary forest mixed with oil palm trees (*Elaeis guineensis)*, and short and tall trees. The vegetation found in this area included a wide variety of grasses, herbs, and shrubs, and trees. The topsoil is of the loamy type but some areas are characterized by clay and loamy. The people living in this community are predominantly farmers specializing in the cultivation of cassava (*Manihot esculenta*), yam (*Oxalis tuberosa*), water yam (*Dioscorea alata*), pumpkin leaves (*Telfaira occidentalis*), plantain (*Musa paradisiaca)*, and Okra (*Abelmoschus esculentus*); while some are into craft making and few are civil servants.

### *2.2. Sampling sites*

The two sampling sites were located along a foot track called Afang Akang with the co-ordinates of N$5^0$12'46.3" and E$7^0 33' 39.4''$ (Figure 1). The fallowed land site is about 200m west of the direction from the cultivated land site. The fallowed land site is an area covered with long and dense trees such as *Guare* sp, and climbers forming a nearly closed canopy and without apparent and reported human impacts for 4years (pers. comm.). The cultivated land site is also characterized by oil palm (*Elaeis guineensis*) trees of various densities of coverage, woody shrubs such as *Chromolaena odorata* (Siam weed), and various grass undergrowth. The cultivated land-use system has the presence of human activities; conventionally tilled with hoes, cropped with melon (*Cucumismelo*), cassava (*Manihot esculenta*), yam (*Oxalis tuberosa*), water yam (*Dioscorea alata*), pumpkin leaves (*Telfaira occidentalis*), waterleaf (*Talinum triangulare*), Okra (*Abelmoschus esculentus*) and maize (*Zea mays*).

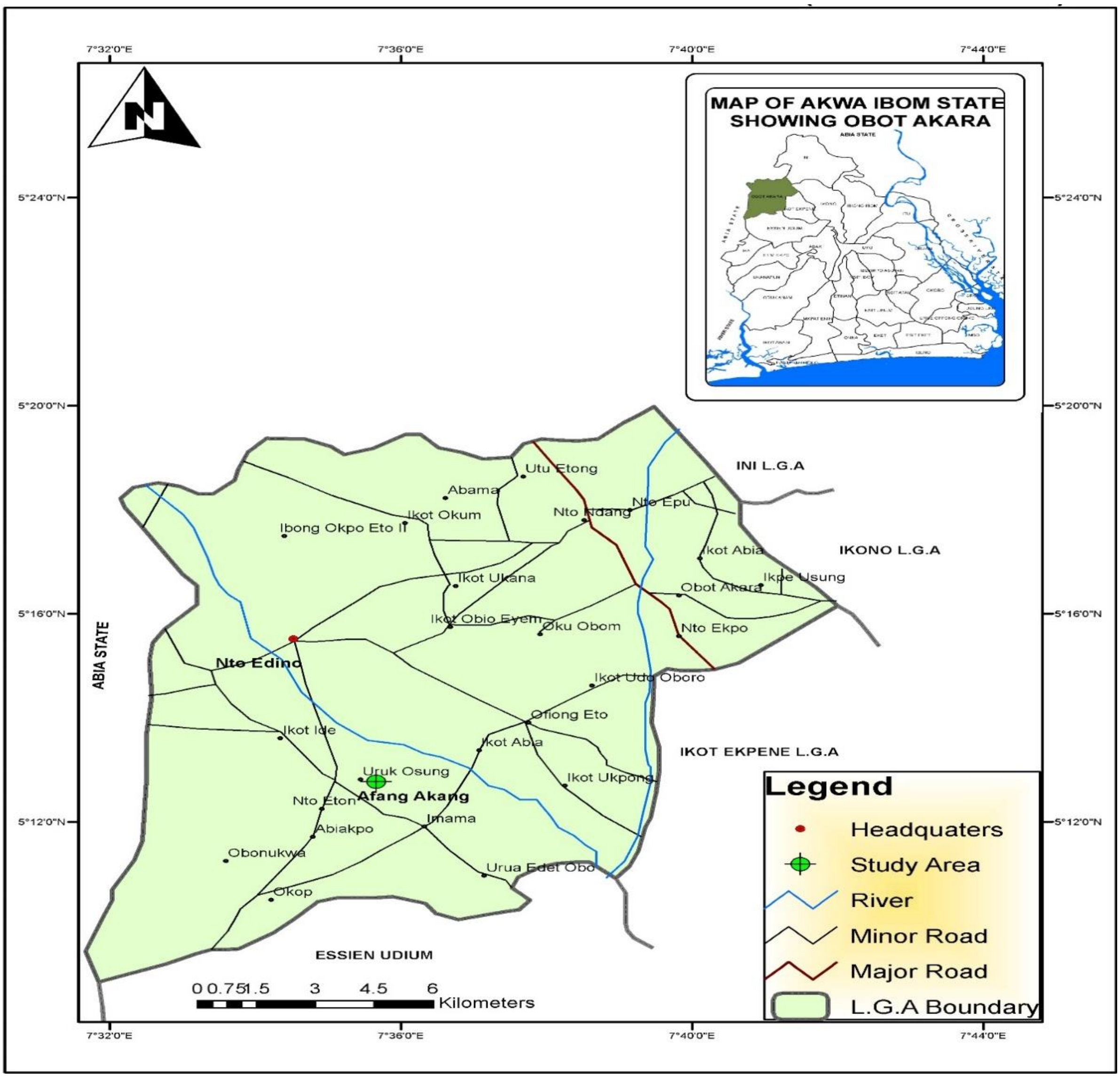


**Figure 1:** Map of Obot Akara LGA showing study area (Afang Akang) (Cartography Studio, Department of Geography and Natural Resources Management, University of Uyo, Uyo, Akwa Ibom State)

*2.3. Methods*

2.3.1 Physico-chemical parameters of soils

The soil samples from fallowed and cultivated land systems were collected and placed in separate polythene bags and taken to the Department of Animal and Environmental Biology Laboratory, the University of Uyo for determination of soil moisture content according to the method described by Jamel (2017). Soil temperature and pH were determined *in situ* with the use of mercury in a glass thermometer and buffered electronic pH meter (Kent 7020) respectively.

2.3.2. Collections of soil sample

Collections of soil samples for the extraction of soil macroinvertebrates were carried out fortnightly twice a month, for four months intervals between May and August 2016. In each of the sampling sites (fallow and cultivated), three sampling macro-plots (A, B, and C) were measured out at 10m × 10m × 10m apart from each other in a triangular transect. Each of the sample macro-plots was divided into two sampling micro-plots (A1, A2, B1, B2, C1, and C2). In each sampling micro-plots, a well-measured and marked tin container (10cm × 10cm) was used in collecting the soil samples at depth of 0-10cm (Battigelli and Marshall, 1993). The soil samples were placed into different polythene bags and labeled carefully to indicate; date of collection, sampling site, and micro-plot collected.

2.3.3. Laboratory analysis
The soil samples were taken to the Entomological Laboratory unit of the Department of Animal and Environmental Biology University of Uyo, for analysis. The elutriation technique according to Alonso-Zarazaga and Domingo-Quero (2010) was adopted to extract soil macro-invertebrates from soil litters. The soil litters were places on a transparent tray with water inside, and with the help of forceps and soft-haired brush, soil macroinvertebrates that floated, were collected and preserved. Berlese – Tullgren Funnel method was also used for the extraction of the soil macroinvertebrates; where each of the soil samples were placed in a funnel (Hopkins, 2002) sealed with a mesh wire size of 1 mm and were allowed to stand under a lighting tungsten bulb of 100watts for 72 hours. The heat energy produced from the lighting bulb extracted the soil organisms through the open narrowed lobe of the funnel. These soil organisms were collected into conical flasks containing 70% ethyl alcohol. The collected soil organisms were sorted, counted, and identified by Entomologist in the Entomological Laboratory unit of the Department of Animal and Environmental Biology and also with the aid of the key identification guides by Borror and White (1970). The scientific name and numbers of each soil macroinvertebrate species were recorded.

2.3.4. Data analysis
Microsoft Excel (version 2007) was used to determine the numerical and percentage of soil macroinvertebrate abundance. SPSS Statistical software (version 2015) was used to determine the Person correlation coefficient ($r$) between the physico-chemical parameters and the soil invertebrate abundance. PAST statistical software was used to determine the diversity indices and the canonical correspondence analysis.

## 3.0. Results and Discussion

### *3.1. Soil physico-chemical parameters*

The range, mean, and standard error of soil physic-chemical parameters measured from the two sampling sites during the study are presented in Table 1. The result of the person correlation showing the relationship between the soil physico-chemical parameters and macroinvertebrate class abundance is presented in Table 2. The result of the analysis showed that soil temperature correlated positively with the abundance of *Clitellata* at ($r$ = 0.851; $p$ < 0.05) and *Insecta* at ($r$ = 0.826; $p$ < 0.05). Similarly, soil pH correlated positively with the abundance of *Diplopoda* with ($r$ = 0.911; $p$ < 0.05). It is also worthy of note that the correlation between soil moisture and the macroinvertebrate class was non-significant at ($p$ < 0.05).

The mean pH value of the cultivated soil site shows the acidic nature of the soil which contrasts the alkaline nature of the fallowed soil. The variation in the soil pH could be due to soil exposure to environmental influences such as leaching and evaporation (Konakwan *et al*., 2015). There was a significant difference at ($p$ < 0.05) in the variation of pH values across the two contrasting soils. Furthermore, the variations observed for soil temperature and moisture in the two contrasting soils could be due to the removal of foliage from the cultivated soil which has often served the purpose of covering the topsoil from direct sunlight and evaporation processes (Alonso-Zarazaga and Domingo-Quero, 2010; Camara *et al.,* 2018).

Concerning soil macroinvertebrates composition and abundance dynamics, the correlation analysis showed positive relationships between soil temperature and pH, and macroinvertebrate classes. It was observed that soil temperature also showed a positive correlation with class Clitellata and Insecta, whereas soil pH correlated positively with class Diplopoda. This implied that the variations in soil temperature and pH affect the composition and abundance of the macro-invertebrates.

The variation of the pH range of the fallowed and cultivated soils showed that the cultivated land site tends to be more acidic than the fallowed soil. This result supports the assertion of Nanganoa *et al*. (2019), that the physico-chemical and biological properties of soil ecosystems are continuously influenced by land uses. It could also be deduced from the results that the fallowed soil with its mean characteristic pH property of 6.93±0.25 recorded a higher abundance of soil macroinvertebrates compared to the cultivated soil. This observation is consistent with the reports of Madge and Sharma (1969) that soil macro-invertebrates strive better in alkaline than acidic soil. This is because the body

fluid of these macroinvertebrates is alkaline which could be hypotonic to the acidic concentration of a degrading cultivated soil environment.

**Table 1:** The range, mean and standard error of the soil physico-chemical parameters measured during the sampling period.

| Soil Parameters | Fallowed Land | | Cultivated Land | |
|---|---|---|---|---|
| | Range | Mean ± Std. Err. | Range | Mean ± Std. Err. |
| pH | 5.26-6.95 | 6.93±0.25* | 3.20-5.10 | 4.43±0.16* |
| Moisture content | 9.50-16.50 | 15.60±1.22$^{ns}$ | 7.00-11.50 | 9.91±0.73$^{ns}$ |
| Temperature ($^oC$) | 30-33.5 | 32.08±0.52* | 29.00-31.5 | 30.95±0.19* |

Keys: (*) mean values are significantly different at ($p < 0.05$); (ns) = mean values not significantly different at ($p < 0.05$)

**Table 2:** Pearson correlation between variations in soil parameter and species abundance

| | Mositure | Temp. | pH | *Clitellata* | *Arachnida* | *Diplopoda* | *Insecta* |
|---|---|---|---|---|---|---|---|
| Mositure | 1 | | | | | | |
| Temp. | 0.184 | 1 | | | | | |
| | 0.727 | | | | | | |
| pH | 0.938** | 0.46 | 1 | | | | |
| | 0.006 | 0.359 | | | | | |
| Clitellata | 0.6 | 0.851* | 0.785 | 1 | | | |
| | 0.208 | 0.032 | 0.064 | | | | |
| Arachnida | 0.282 | 0.69 | 0.413 | .827* | 1 | | |
| | 0.588 | 0.13 | 0.416 | 0.042 | | | |
| Diplopoda | 0.784 | 0.664 | 0.911* | 0.820* | 0.47 | 1 | |
| | 0.065 | 0.151 | 0.011 | 0.046 | 0.347 | | |
| Insecta | 0.147 | 0.826* | 0.385 | 0.818* | 0.906* | 0.557 | 1 |
| | 0.781 | 0.043 | 0.451 | 0.047 | 0.013 | 0.251 | |

### *3.2. Soil macroinvertebrates composition, abundance and diversity*

The species composition, numerical and percentage abundance of soil macroinvertebrates are presented in Table 3, while the results on the community structure of the soil macroinvertebrates classes are presented in Table 4. A total of 17 soil macroinvertebrates species comprising of 11 orders, four classes were encountered during the study period. The most abundant macroinvertebrate species in the fallowed land system were in the order; *Cryptotermes* sp 67(20.49%) > *Blatta* sp 56(17.12%) > *Lumbricus terrestris* 45(13.76%) with *Hogna* sp 1(0.0.30%) as the least; whereas the pattern encountered in the cultivated land was, *Cryptotermes sp*. 79(41.58%) > *Lasius sp* 30(15.79%) > *Lumbricus terrestris* 21(11.05), with *Paraponera sp* 1(0.53%) as the least abundant species. Notably, Class *Insecta* was observed to be higher in the two sampling land used systems with percentage abundance of 74.6% and 80.6% in the fallowed land and cultivated land respectively, whereas while Class *Arachnida* represented the least Class of soil macroinvertebrate species in the fallowed land system, they were absent in the cultivated land used system.

The result for the diversity indices of soil macroinvertebrate group across the two contrasting sampling land used systems is presented in Table 5. A total of 16 individual species were observed in the fallowed land as compared to 9 individual species recorded for the cultivated land, this means that the ratio of soil macro-invertebrate species between fallowed and the cultivated land was about 2:1. A Higher Shannon Weiner index of H = 2.332 was observed in the fallowed land compared to a lower value of 1.765 observed for the cultivated land. A similar trend was also observed for the Margalef index where a higher value of 2.591 was recorded for the fallowed land compared to the value of 1.529 recorded for the cultivated land.

In the present study, earthworm (*Lumbricus terrestris*) and termite (*Cryptotermes* sp) were dominant both in the fallowed and cultivated land than all other soil macroinvertebrate species encountered in the study. These could be attributed to their ecological niche as important drivers of soil aggregation, soil porosity, water infiltration, and resistance to erosion in any soil ecosystem (Lavelle, 1997). These activities can lead to soil structure reformation, increased aeration, water infiltration, and water availability to plants (Brown *et al*., 2004). This observation agrees with the report of Brown *et al.* (2004), who reported that termites, ants, and earthworms make up the most abundant of soil macro-invertebrates across most soil ecosystems.

*Lumbricus terrestris* in particular, plays the role of soil organic matter and cast formation enriched with soil nutrients such as nitrogen, potassium, phosphorus, and calcium which serve as plants' nutrients reservoir (Mora *et al*., 2003; Pulleman *et al*., 2004; Bossuyt *et al*., 2005). The population of *Lumbricus terrestris* in the cultivated site was less in abundance as compared to that of the fallowed site. This could be attributed to human disturbances as a result of soil cultivation practices such as deforestation, bush burning, soil tillage and the application of agrochemicals which is very detrimental to not only the *Lumbricus terrestris* population, but also to the overall population dynamics of soil macroinvertebrates in the cultivated land system.

The activities of *Cryptotermes* sp includes the construction of mounds, nests, and surface sheeting, and this brings about transportation of organic material and soil burrow, which improve drainage and aeration. Collin (1983) reported that termites engage in litter removal and breakdown to form soil nutrients, but the high abundance of termite in a cultivated land system such as encountered in this study could become a potential threat to crop yield (Rossi *et al.*, 2010). The agricultural effect of *Cryptotermes* sp has been well documented in the work of Sekammatte *et al*. (2003) and Sileshi *et al.* (2005).

The nature of a soil structure, whether fallowed or cultivated can exert a strong influence on the overall composition and abundance of soil macroinvertebrates in a given ecosystem (Barrios *et al*., 2002; Barrios *et al*., 2005). However, the higher abundance of soil macro-invertebrates observed in the fallowed land could be as a result of its stable and isolated nature with little or no human activities over time (Lagerlöf *et al*., 2002; Rossi *et. al.*, 2010). The fallowed land system has better soil covers which are necessary for the survival of soil macroinvertebrates. In addition, the soil of the fallowed land system is minimally disturbed. According to Moreira *et al.* (2008) and Rossi *et al.* (2010), these features create more favourable conditions for the development and survival of soil organisms, and the absence of soil cover and minimal soil disturbance in the cultivated land system results in soil degradation and lack of food and microhabitats which are necessary for the development and survival of the soil macroinvertebrates.

**Table 3:** The composition and abundance of soil macroinvertebrates from the two sampling sites

| | | | Abundance | | | |
|---|---|---|---|---|---|---|
| | | | Fallow land | | Cultivated land | |
| Class | Order | Species composition | Ni | (%) | Ni | (%) |
| Clitellata | Haplotaxida | *Lumbricus terrestris* | 45 | 13.76 | 21 | 11.05 |
| Arachnida | Araneae | *Hogna* sp | 1 | 0.30 | 0 | 0 |
| Diplopoda | Spirostreptida | *Archispirostreptus gigas* | 3 | 0.92 | 0 | 0 |
| | Julida | *Blaniulus guttulatus* | 34 | 10.40 | 11 | 5.79 |
| Insecta | Blattodea | *Blatta* sp | 56 | 17.12 | 12 | 6.32 |
| | Coleoptera | *Phyllophaga* sp | 21 | 6.42 | 14 | 7.37 |
| | Dermaptera | *Chelisoches* sp | 6 | 1.84 | 0 | 0 |
| | | *Forficula* sp | 17 | 5.20 | 0 | 0 |
| | Hymenoptera | *Solenopsis* sp | 15 | 4.59 | 0 | 0 |
| | | *Lasius* sp | 5 | 1.53 | 30 | 15.79 |
| | | *Paraponera* sp | 2 | 0.61 | 1 | 0.53 |
| | | *Monomorium* sp | 30 | 9.17 | 0 | 0 |
| | | *Sphex* sp | 0 | 0 | 5 | 2.63 |
| | Hemiptera | *Neotibicen* sp | 10 | 3.06 | 0 | 0 |
| | Orthoptera | *Gyllus* sp | 10 | 3.06 | 0 | 0 |
| | | *Zonocerus veriegatus* | 5 | 1.53 | 17 | 8.95 |
| | Isoptera | *Cryptotermes* sp | 67 | 20.49 | 79 | 41.58 |
| TOTAL | | | 327 | | 190 | |

Ni = Number of Individual; (%) = abundance.

**Table 4:** Community structure of soil macroinvertebrate class from the two sampling sites

| | Fallowed land | | Cultivated land | |
|---|---|---|---|---|
| Class | Numerical abundance | (%) Abundance | Numerical abundance | (%) Abundance |
| Clitellata | 45 | 13.8 | 21 | 11.1 |
| Arachnida | 4 | 1.2 | 0 | 0 |
| Diplopoda | 34 | 10.4 | 11 | 5.8 |
| Insecta | 244 | 74.6 | 153 | 80.5 |

**Table 5:** The diversity indices of the soil macro-invertebrates of the two sites

| Diversity indices | Fallowed land | Cultivated land |
|---|---|---|
| Taxa_S | 16 | 9 |
| Individuals | 327 | 190 |
| Dominance_D | 0.1212 | 0.2353 |
| Shannon_H | 2.332 | 1.765 |
| Evenness | 0.644 | 0.649 |
| Margalef index | 2.591 | 1.529 |

## 4.0. Conclusions

In conclusion, human activities such as soil cultivation practices could greatly impact negatively on the population dynamics of soil macroinvertebrates. The impact does not only caused a shift in the soil physico-chemical properties but also greats a gap in the ecosystem processes due to the decline or elimination of some soil macroinvertebrate species, which play important ecological roles in soil nutrient recycle and other soil ecosystem functions.

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